

## PATENT SPECIFICATION

942,261

DRAWINGS ATTACHED.

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942,261



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## COMPLETE SPECIFICATION.

## Continuous Adsorption Apparatus.

We, METALLGESELLSCHAFT AKTIEN-GESELLSCHAFT, of 14 Reuterweg, Frankfurt-on-the-Main, Germany, a body corporate organised under the laws of Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 This invention relates to apparatus for the continuous recovery of vapours from gases, for instance of solvent vapours from the exhaust air of industrial plants, by adsorption in stationary non-agitated adsorbent beds.

15 Many of the known continuous adsorption processes make use of moving adsorbent beds which are maintained in a state of violent motion or fluidised by the introduction of a stream of gas, and which by gravity or pneumatic convection are cycled through the adsorption stage, the regeneration stage, and other treatments which serve for the enrichment of the adsorbate, the drying of the adsorbate, and the like.

20 Other continuous processes use adsorbents in packed beds built up in a cellular container forming a hollow cylinder. Rotation of the hollow cylinder carries the adsorbent layers around the axis of revolution and brings the inlet and exit openings of the several adsorbers into register with the admission and exit lines of the treated gas, the steam, the coolant, and the like, in succession. Such drum adsorbers have been built for rotation about vertical and horizontal axes. This principle of construction has incidentally also been applied to regenerative heat exchangers in which the

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adsorbent is replaced by solids for the storage of heat. 40

It has also been proposed in stationary cellular adsorption apparatus to locate the connecting openings to the cells in concentric circles in planes in which, as is the case in a slide valve, rotatable co-operating members are provided for establishing connections between the adsorber entries and exits and the several admission and exit pipes, so that rotation permits these connections to be made in sequence. However, these designs are only suitable for smaller plant, because the large sealing faces of the line change members, when their dimensions are considerable, become unreliable in operation due to the difference in the temperatures obtaining in the several entry and exit lines. 50 55

The replacement of such sliding line-change members by a control box in which the connections are formed by channels with liquid seals, the box being first lowered, then rotated, and finally raised again for effecting a change-over between the lines, has not been a success because of the different temperatures and pressures in the several adsorber cells. 60 65

The periodic change-over of the connections of individual stationary adsorber units between the admission and exit pipes comprised in the several operating lines calls for the provision of a major number of branch connecting pipes and of shut-off and two-way valves. Since these valve elements must be operated simultaneously in groups, automatic control of such a plant requires considerable apparatus and is expensive, apart from its liability to develop faults. 70 75

In the technique of adsorption processes

the particular characteristics of discontinuous processes in which a plurality of stationary containers filled with an adsorbent are connected alternately in a given sequence with the admission and exit pipes for the treated gas, the regenerating medium, the coolant, and the like, offer great advantages. In a stationary bed of activated carbon which is at rest, the risk of undue formation by attrition of the adsorbent is lower than in other processes. Consequently, local accumulations of dust, preferential gas channels, and creeping irruptions of adsorbate will not occur. Moreover, stationary adsorbent beds of substantial depth offer the advantage of having considerable functional reserves, of giving excellent yields and of permitting the exploitation of the so-called extraction effect, all these factors permitting the adsorbed solvent to be desorbed with a minimum expenditure of energy.

The present invention relates to a continuous adsorption apparatus which makes use of stationary adsorbent layers which are at rest, and is based upon a proper appreciation of the fact that in many applications, for instance in the recovery of solvent vapours from the exhaust air of industrial undertakings, a division of the overall process into the two operations of adsorption and desorption with the omission of a drying and cooling period after desorption, is a possibility.

The drying of the adsorbent, after steam regeneration, can be combined with the process of adsorption if the treated gas is introduced to the adsorbent at elevated temperature. Heating may be effected by admixture of hot inert gases or by direct heat supply through heat storage means located in the adsorber on the exit side of the desorption medium, for instance underneath the adsorbent bed. In the desorption stage the heat storage medium which is cold at first is exposed to the flowing steam-desorbate mixture. This condenses and yields its heat to the heat storage medium which is thereby heated. When the issuing steam is clean the temperature of the heat storage medium may be about 100° C. In the following adsorption stage the heat storage medium is on the entry side of the untreated gas. The untreated gas thus accepts heat from the heat storage medium. This is consumed in the adsorbent layer for evaporating the moisture which adheres to the adsorbent. The moisture leaves together with the purified gas. In other words, the drying and adsorption processes are simultaneously performed.

According to the present invention there is provided apparatus for the continuous recovery of vapours from gases, comprising two coaxial chambers which are relatively sealed in a gas-tight manner, each chamber

being provided with a connection for the admission and discharge of the treated gas, a plurality of adsorbers connected in parallel with said chambers, a rotatable shaft extending axially through said chambers and passing through the chamber walls in gas-tight manner, said shaft being formed with hollow ends for the admission and discharge of a desorbent, pipes branching laterally from the hollow portions of said shaft and terminating in spring-loaded flanges adapted to be brought into register with and to seal the connections in the two chambers from one or a group of adsorbers for the purpose of connecting the same into the line of flow of the desorbing medium, and means for axially separating said flanges from said connections when another adsorber or group of adsorbers is to be treated with the desorbent.

This apparatus is capable of providing a large flow section to the treated gas and a favourable relationship between cross section and depth of the adsorbent bed, which is especially useful when the concentration of the solvent is low and below the explosive level.

The apparatus permits the division of the overall process into two operations in such manner that a large volume of adsorbent is available to be charged in several parallel beds, whereas a small volume of the charged adsorbent is submitted to a rapid and intense regeneration without subsequent drying and cooling, and thus permits a substantial simplification in the construction of the line-changing equipment because the change-over comprises but a single step.

The adsorber connections in each of the two chambers are arranged in a circle and are located in a plane or on the surface of a cylinder. The two circles of openings in the two chambers are disposed concentrically the one above the other. Located in the axis of the circles is a rotatable shaft which passes through a gas-tight seal in the dividing wall between the chambers. The ends of the shaft are tubular, that is to say, they are hollow. In both chambers branch pipes extend from the hollow portions of the shaft, said pipes being coplanar and their open ends fitted with spring-loaded seals.

These seals can be brought into gas-tight register with the ends of the connections to each adsorber by rotation of the shaft. When in register one hollow end of the shaft is in direct communication through the adsorber with the other hollow end of the shaft for the admission and discharge of the desorbent steam. By indexing the shaft, the adsorbers associated with the casing can be alternately brought into the desorption line in succession. The spring-loaded seals which consist of spring bellows with seal-

ing lips can be contracted by appropriate means before rotation of the shaft, and again relaxed when the indexing rotation is completed, or alternatively the shaft may be lifted before it is rotated and lowered again when rotation is completed. During the process of changeover the supply of steam to the hollow shaft is stopped.

In order to enable the invention to be more readily understood, reference is made to the accompanying drawings which illustrate diagrammatically and by way of example, various embodiments of plant suitable for carrying the same into practical effect and in which:—

Fig. 1 is a vertical section of the line-changing apparatus in adsorber plant in accordance with the invention, in which the ends of the line-changing connections are disposed in two planes and the line-changing shaft passes through a parting wall between the chambers in a stuffing box.

Fig. 2 is a modification of the form of construction shown in Fig. 1, in which the seal between the chambers is a liquid seal.

Fig. 3 is a horizontal section of the apparatus shown in Figs. 1 and 2 taken on the line I—I.

Fig. 4 is a form of construction in which the ends of the line-changing connections are disposed on the periphery of a cylinder.

Fig. 5 shows a complete installation for performing the herein described process in vertical section.

Fig. 6 is a horizontal section of the installation illustrated in Fig. 5, taken on the line II—II.

The line-changing apparatus shown in Fig. 1 substantially consists of a casing 1 divided into two chambers 3 and 4 by a gas-tight partition wall 2. Pipe bends 5 connect the interior of the upper chamber 3 and pipe bends 6 the interior of the lower chamber 4 with the inlets and exits of adsorbers 7 outside the casing.

The bottom 8 of the casing has a flanged connection 9 for the admission of the gas for treatment. The cover 10 of the casing has a similarly flanged connection 11 for the discharge of the gas after treatment into a stack not specially shown in the drawing.

Located axially in the preferably cylindrical casing 1, is a shaft 12 which rotatably and axially shiftably passes through floor 8, parting wall 2, and cover 10 in gas-tight seals formed by stuffing boxes 13, the upper end of the shaft being provided with a gearing 14. The hollow ends 15, 16 of shaft 12 connect with branch pipes 17, 18 which have terminal fittings in the form of spring bellows 19, 20 with sealing flanges 21, 22. These sealing flanges can be brought into register by rotation of shaft 12 with co-operating flanges 23, 24 at the end of the pipe bends 5 and 6 which connect with the

adsorbers. These terminal flanges in both chambers are coplanar and arranged concentrically around shaft 12, as will be seen by reference to Fig. 3.

Inside the upper chamber 3, the upper end of the shaft is formed with openings 25, and this part of the shaft is surrounded by a steam-tight chest 26 which is connected by a bend 27 with the connecting flange 28 for the steam admission pipe.

In the position of the line-changing apparatus shown in Fig. 1, adsorber 7 on the left-hand side is in the desorption line. In Fig. 3 adsorber 7a is in the desorption line. The other adsorbers 7b are in course of being charged.

The steam passes through adsorber 7a in downflow. The steam passes from a pipe (not shown in the drawing) which is connected with flange 28, through bend 27, chest 26, openings 25, and pipe 17 into the adsorber and leaves through pipe 18 and the lower hollow end 16 of shaft 12, whence it enters condensing plant of conventional construction.

In order to bring the neighbouring adsorber into the desorption line, the steam is first shut off by the closing of a valve in the steam admission pipe. With the aid of gearing 14, shaft 12 is lifted until flanges 21, 23, on the one hand, and 22, 24, on the other hand, lose contact. The shaft is then indexed until the terminal flanges 21, 22 of pipes 17 and 18 register with the pipe ends which communicate with the next adsorber. The shaft is lowered again and the valve in the steam admission pipe reopened. These operation steps are performed by the gearing in accordance with a programme. The initiation of the line-change operation may be timed to occur at constant intervals, or the change may be controlled by a concentration meter located in the exhaust air duct of the plant, the meter responding to the presence of solvent vapour in the exhaust air and initiating the line-change operation. The air sample for the concentration meter may be conveniently picked up from the end of a rotatable swivel arm which precedes the line-changing gear, the sample being taken in the line of the exit from the next adsorber due for steaming, which may be expected to be the next to saturate.

The apparatus shown in Fig. 2 differs from that described with reference to Fig. 1 in that the seal between the two chambers in the casing is formed by a liquid seal. Corresponding parts in the two drawings are indicated by the same reference numerals. The dividing wall 2 in Fig. 2 is rigidly mounted on shaft 12 and rotates together with the shaft. The periphery of the dividing wall 2 is fitted with a cylindrical wide annular skirt 50 which projects into the

receptacle 51 of the liquid seal. This receptacle has lateral connecting pipes 52 and 53, water being continuously introduced through the upper and discharged through the lower pipe. This water can be used elsewhere, for instance for the purpose of cooling the untreated gas or to serve as a coolant in the desorbate condenser. The described arrangement ensures that the receptacle of the water seal will always be full of water.

In the apparatus shown in Fig. 4, the ends of the adsorber connections in both chambers are located on the shell of a cylinder, for instance in two zones of the shell of the cylindrical casing. In this form of construction the terminal flanges of the branch pipes from the central shaft are withdrawn from the terminal flanges on the ends of the connections of the adsorbers, not by axially shifting the shaft, but by contracting the spring bellows with the aid of hydraulically controlled pistons or magnetic actuators.

In Fig. 4 the casing of the line-changing apparatus is marked 101. The ends of the casing are closed by cover 102 and a floor 103, and the casing is centrally divided into chambers 105 and 106 by a partition wall 104. The flanges 107, 108 at the end of the pipe connections to the adsorbers 109 are arranged in chambers 105 and 106 in circles around the shell of the casing. The ends of branch pipes 113, 114 from the hollow ends 110, 111 of shaft 112 carry spring bellows 115 fitted with flanges 116, 117 which can be moved into register with the adsorber connections.

The flanges 116, 117 are linked by rods 118 with the hydraulically operated pistons or magnetic actuators 119 which are supplied through lines 120 with water under pressure or with electric current. For changing the steam line from one adsorber to the next a valve in the steam pipe is first closed, as already described in conjunction with Figs. 1 and 2. The electric circuits of the magnetic actuators 119 are then energised and the actuators contract the spring bellows 115, thereby raising the terminal flanges 116, 117 from the co-operating flanges 107 and 108 of the adsorber connections. The shaft is then indexed by its gearing 121 into the next position of register. De-energisation of the circuits of the magnetic actuators 119 permits the spring bellows 115 to re-expand and the terminal flanges 116, 117 to apply themselves to the next set of co-operating flanges for establishing a good joint. Finally, the valve in the steam admission pipe can be reopened and this completes the line-change operation.

Fig. 5 illustrates an adsorber installation which forms a compact, completely self-contained unit comprising a filter, a cooler,

a blower for the treated gas, a condenser, and a separator for the desorbate-steam mixture. This auxiliary equipment and the gearing for rotating the line changer shaft are located below the adsorber cells. The illustrated installation differs from that shown in Figs. 1 to 4 in that the ends of the adsorber connections are located in two coplanar concentric circles, as shown clearly in Fig. 6.

Eight adsorbers 201, each in a cell of circular segmental cross-section, are built together to form a hollow cylinder. In each adsorber, the adsorbent layer 202 is superimposed upon a base of heat storing materials 203 which rests on a gas-pervious bottom 204. Conveniently, the upper faces of the adsorber casings are provided with flanged openings 205 located in a circle.

On the inside of the hollow cylinder formed by the adsorbers, each adsorber casing is formed with a lateral opening 206 below the perforated bottom 204, and a pipe 207 rises upwards terminating in the plane of the upper openings in the adsorber casings, where they are likewise fitted with a terminal flange 208. Interposed between the pipes and the inner wall of the adsorber cells is a receptacle 209 for forming a liquid seal. Through a pipe 210 this is kept full of water to the level of an overflow 211.

The line-changer shaft 212 extends in the axis of the hollow cylinder. The shaft forms a tube which is divided by a transverse wall 213. This tubular shaft is operable through gearing 214 and its lower end is provided with openings 215 surrounded by a steam-tight chest 216 which communicates through a pipe 217 with a condensing unit. In this chest and in the cover plate of the line changer casing at its upper end the shaft is rotatably and axially shiftably held in stuffing boxes 218 which form steam-tight seals.

Affixed to the shaft is a bell 219 and the cylindrical skirt of the bell is arranged to project into the receptacle 209 of the water seal which separates the two line changer assemblies. The pipes 207 which connect with the bottom ends of the adsorber cells communicate with the chamber under the bell. The openings 205 in the top of the adsorber cells are located above the bell.

A pipe 220 branches laterally from the upper end of the hollow shaft and its end is fitted with a spring bellows 221 with a flange 222. This flange registers with the circle of openings 205 at the top of the several adsorber cells. Below bell 219 is a passage 223 which terminates in a second spring bellows 224 fitted with a flange 225 and which connects with the lower part of the hollow shaft. This latter flange is located at the end of the radius of the circles formed by the flanges 208 at the ends of

pipes 207. In the operating position illustrated in Figs. 5 and 6, the adsorber on the right is in the desorption line. From a pipe (not shown) the steam flows through the upper portion of the hollow shaft 212 and pipe 220 and thence through the adsorber in downflow. After having passed through the adsorber the steam rises through pipe 207, flows through channel 223 and the lower portion of the hollow shaft and then emerges through the openings 215 into chest 216 whence it is taken to a condenser 230 through the connecting pipes 217. Through pipe 231 the condensate flows into separator 232 from which the desorbate, forming the top layer, is withdrawn through pipe 223, whereas the lower layer, consisting of water, is drained off through pipe 234. If the substance which is to be recovered from the exhaust air is partly or wholly water-soluble the separator is replaced by other apparatus of known kind for dealing with the desorbate water mixture.

The other seven adsorbers are in the adsorption line and, with respect to gas flow, they operate in parallel through the line changer casing. The treated gas enters at 240, and, after passing through a filter 241 and a cooler 242, it is forced by blower 243 into the chamber under the bell. From this chamber the gas stream is distributed between the several adsorbers, descending through duct 207 and entering the adsorbers through the heat storage bed before passing through the adsorbent. From the upper outlet openings 205 the clean gas then reaches the chamber between casing and the top of the bell, leaving the plant via outlet 244.

When it is desired to change the lines the admission of steam is first stopped, as already explained with reference to Figs. 1 and 2. The gearing then raises the shaft, indexes the same into the next position of register, and then re-lowers it.

The change-over is controlled by a concentration meter 250 which indicates the irruption of adsorbate through one of the adsorbers. The air sampling tube 251 for this meter is attached to an arm 252 on the line changer shaft and is carried across the exit openings 205 from the adsorber cells on the end of said arm as the shaft performs its indexing motion.

In Fig. 5 the arm is shown schematically. In relation to pipe 220 the angular position of the arm is such that the air sampling tube rotates ahead of the connecting pipe 220. Consequently, the controlling meter will initiate a line-change when that adsorber which immediately follows the adsorber which is being regenerated is fully saturated.

Conveniently, the number of adsorbers built into an installation in accordance with the invention should be such that at least

$\frac{3}{4}$  of the total adsorbent contained in the cells is in the adsorption line, whilst the remaining  $\frac{1}{4}$  to  $\frac{1}{2}$  is in the desorption line for regeneration by steam. Consequently the number of adsorbers comprised in the installation should be at least three and generally six to twelve.

In order to ensure that the desired rate and intensity of regeneration is maintained in larger installations, each chamber of the line changing assembly may be provided with two pipes branching laterally from the central shaft, possibly at a relative angle of  $180^\circ$ , in such manner that two adsorber cells are in the desorption line at the same time.

#### WHAT WE CLAIM IS:—

1. Apparatus for the continuous recovery of vapours from gases, comprising two coaxial chambers which are relatively sealed in a gas-tight manner, each chamber being provided with a connection for the admission and discharge of the treated gas, a plurality of adsorbers connected in parallel with said chambers, a rotatable shaft extending axially through said chambers and passing through the chamber walls in gas-tight manner, said shaft being formed with hollow ends for the admission and discharge of a desorbent, pipes branching laterally from the hollow portions of said shaft and terminating in spring-loaded flanges adapted to be brought into register with and to seal the connections in the two chambers from one or a group of adsorbers for the purpose of connecting the same into the line of flow of the desorbing medium, and means for axially separating said flanges from said connections when another adsorber or group of adsorbers is to be treated with the desorbent.

2. Apparatus as claimed in Claim 1, in which the partition wall is affixed to a shaft and is sealed by a liquid seal.

3. Apparatus as claimed in Claim 1 or 2, in which the flanges at the end of the adsorber connections in each chamber are coplanar, and in which the shaft is axially shiftable as well as rotatable, the arrangement being such that axial movement of said shaft axially separates said flanges from said connections.

4. Apparatus as claimed in any one of Claims 1 to 3, in which the flanges at the end of the adsorber connections are all located in the same plane, and disposed in two concentric circles.

5. Apparatus as claimed in Claim 1 or 2, in which the flanges at the end of the adsorber connections are located in the chamber walls and the flanges are bonded by spring bellows which are contractable by draw means for the purpose of withdrawing the flanges at the end of the branch pipes

from the co-operating flanges of the adsorber connections.

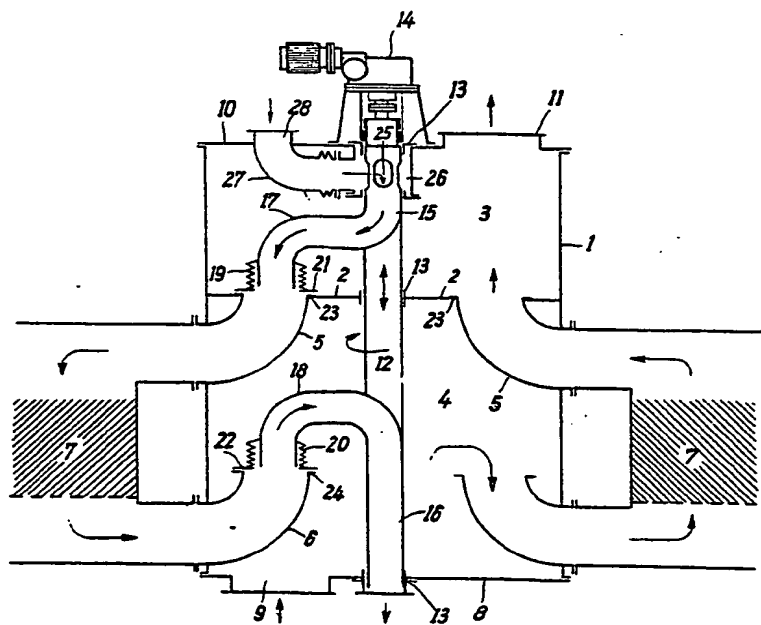
6. Apparatus as claimed in any one of Claims 1 to 5, and further comprising a
- 5 sampling tube which is indexed one step ahead of the line changer pipes, said sampling tube being suspended from an arm on the shaft above the ends of the adsorber connections and being connected with a
- 10 metering device for detecting the presence of adsorbate on the exit side of the absorber.

7. Apparatus for the continuous recovery of vapours from gases, constructed, arranged and adapted to operate substantially as described with reference to the 15 accompanying drawings.

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Fig. 1



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COMPLETE SPECIFICATION

4 SHEETS

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Sheets 1 & 2

Fig. 2

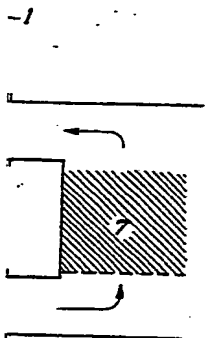
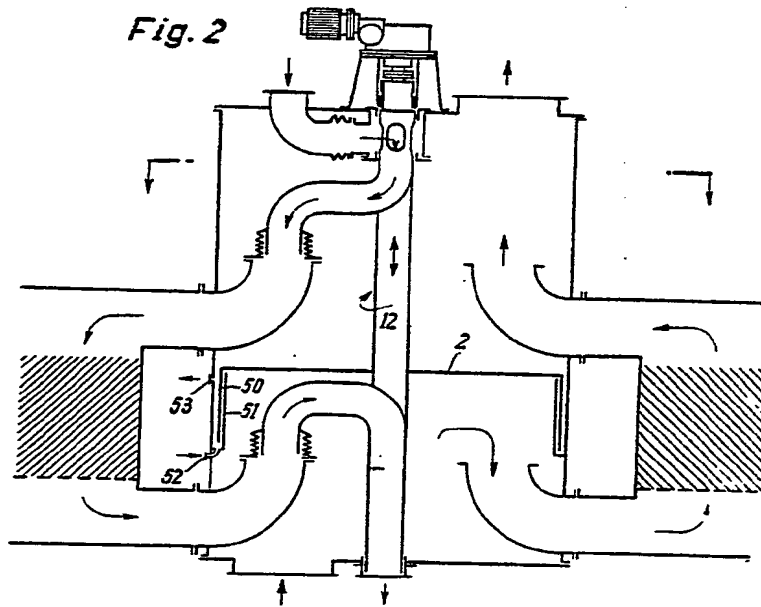
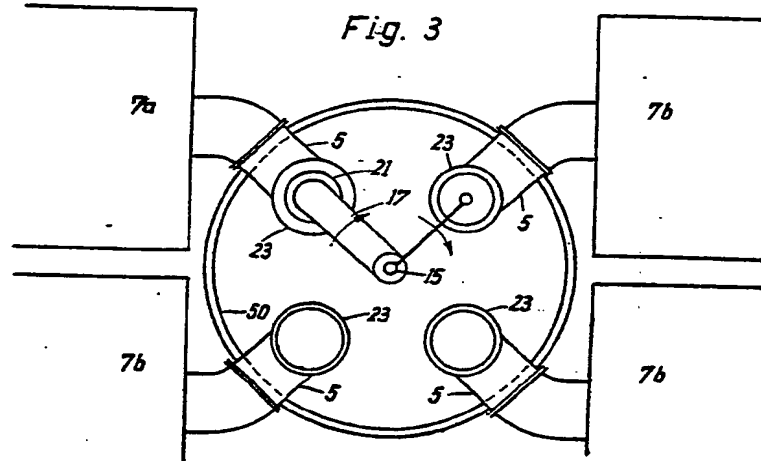


Fig. 3





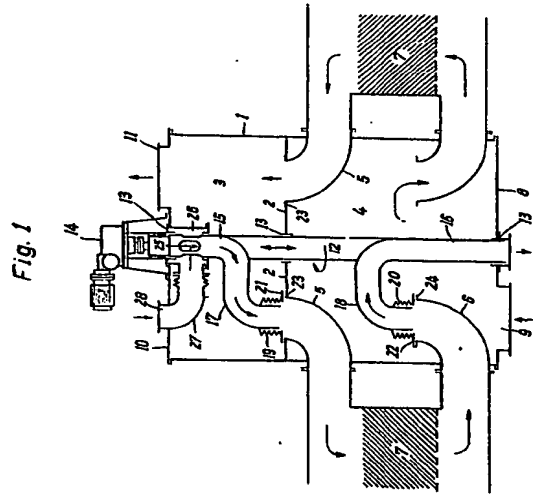
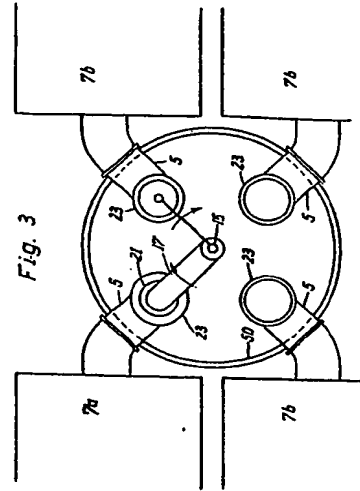
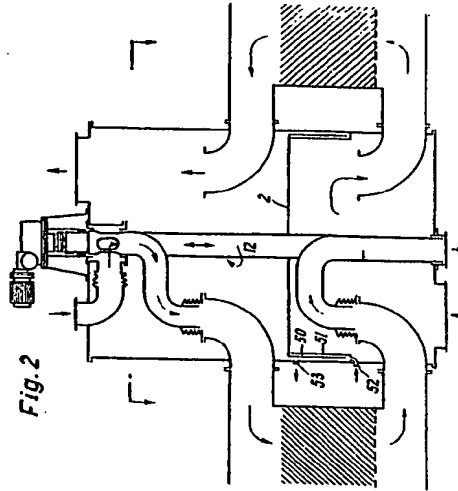
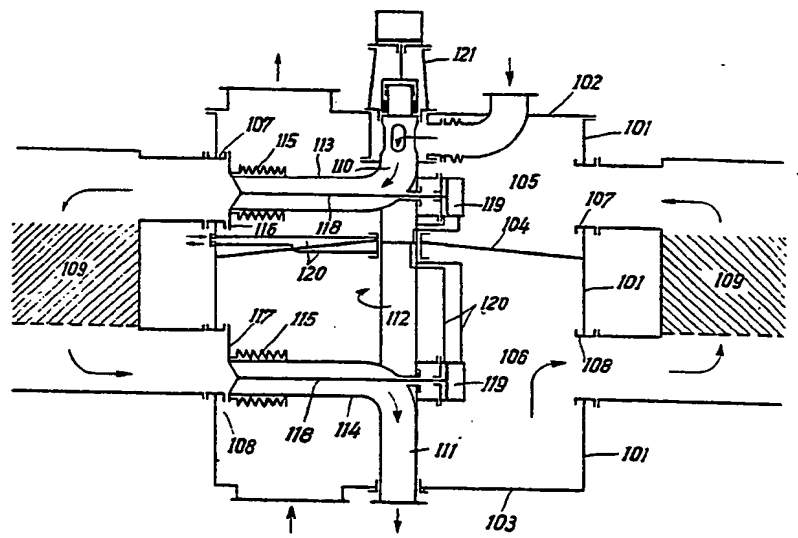


Fig. 4





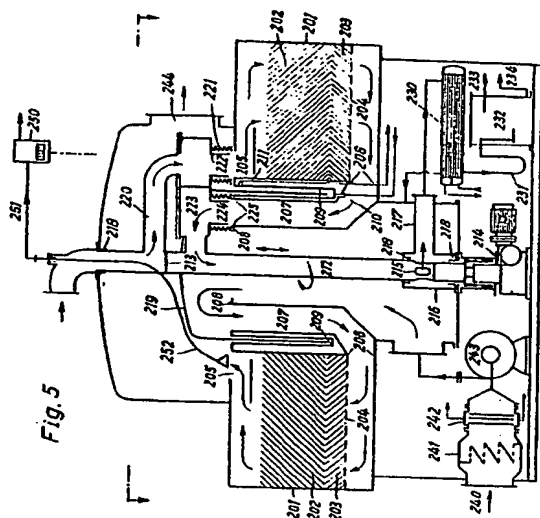


Fig. 5

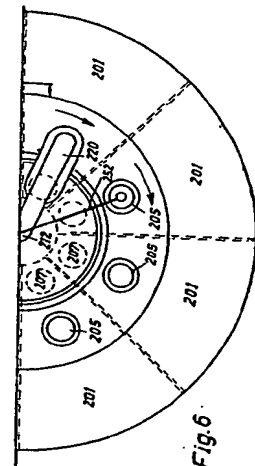
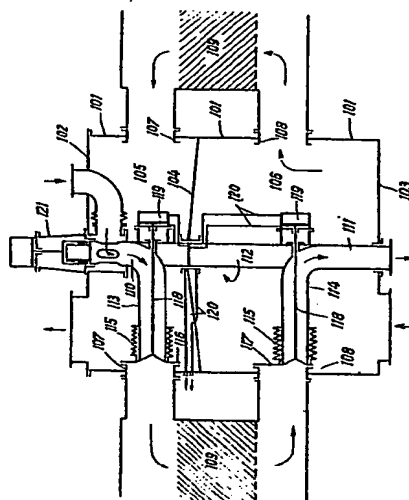


Fig. 6

Fig. 4



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